

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : C08J 5/18, H02G 15/00	A1	(11) International Publication Number: WO 91/18045 (43) International Publication Date: 28 November 1991 (28.11.91)
(21) International Application Number: PCT/US91/02422 (22) International Filing Date: 9 April 1991 (09.04.91) (30) Priority data: 527,525 23 May 1990 (23.05.90) US (60) Parent Application or Grant (63) Related by Continuation US 527,525 (CIP) Filed on 23 May 1990 (23.05.90) (71) Applicant (for all designated States except US): MINNESOTA MINING AND MANUFACTURING COMPANY [US/US]; 3M Center, Post Office Box 33427, Saint Paul, MN 55133 (US).		(72) Inventor; and (75) Inventor/Applicant (for US only) : YAU, Steven, D. [US/US]; Post Office Box 33427, Saint Paul, MN 55133 (US). (74) Agents: NEAVEILL, Darla, P. et al.; P.O. Box 33427, Saint Paul, MN 55133 (US). (81) Designated States: AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), US. Published <i>With international search report.</i>
(54) Title: HIGH STRETCH ELASTOMERIC PRE-STRECHTED TUBES (57) Abstract <p>Elastomeric, low modulus pre-stretched tubular articles supported by removable cores. Embodiments of the articles include those useful for insulators on power cables, and for dielectric stress control of cable splices and terminations. A conductive article is useful for shielding high voltage cables. The articles have low Shore A hardness values and low moduli which allow large expansion ratios and increased wall thicknesses when compared to conventional pre-stretched tubes.</p>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland	KR	Republic of Korea	SN	Senegal
CI	Côte d'Ivoire	LI	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark				

HIGH STRETCH ELASTOMERIC PRE-STRETCHED TUBES

5

Background of the InventionField of the Invention

The invention relates to a multiplicity of elastomeric articles in the form of pre-stretched tubular members supported on removable cores. The articles may be used to provide insulation, dielectric stress control or shielding for spliced or terminated medium voltage and high voltage power cables. Additionally, the tubular members may be used as sleeves for sealing pipes or conduits.

15

Description Of The Prior Art

A pre-stretched tube (PST) is a tubular member which is supported in a stretched condition on a support member, usually in the form of an easily removable core. The core of the PST can be external, i.e., on the outside of the tubular member, or it can be inside the tubular member, as is taught in U. S. Patent No. 3,515,798, (Sievert), incorporated herein by reference. It is disclosed that the core is preferably an internal one-piece rigid spiral core having interconnected adjacent coils in a closed helix configuration.

Pre-stretched tubes have several major applications in the electrical industry. They are used in the repair of electrical cables. They are often used to protect spliced connections such that the spliced cable is threaded through a PST carrying support core which has an internal diameter larger than the outside diameter of the cable. With the PST positioned over the cable splice, the plastic core is removed allowing the stretched elastomeric material to recover, approaching its original size, so that the tubing fits snugly over the repaired section of cable.

30

35

While the major use of conventional PSTs has been as

-2-

insulating sleeves, certain PSTs may also be used as stress control tubes in a cable termination or spliced cable. Such an application is disclosed in U.S.

3,585,274, (Tomaszewski et al.) which describes a stress
5 control tube composed of high permittivity material
containing one or more titanates and/or titanium dioxide.
Preferred permittivity levels are disclosed to be at
least 5 to 10 times the permittivity of the high voltage
cable. U.S. 4,053,702 (Erickson et al.) also discloses a
10 stress control element in the form of a tube which may be
slid into place over the end of a terminated cable. The
tube comprises a non-rigid elastomeric material.
Titanium dioxide is used to provide permittivity levels
in the range of from 10 to 25.

15 U.S. 4,363,842 (Nelson) also discloses the use of
high permittivity pre-stretched tubes. It is disclosed
that the filler concentration must not be too large or
the PST will lose elastomeric characteristics, and fail
to fully collapse when the core is removed. This will
20 leave gaps between the power cable and the PST.

The extent of stretching is related to the hardness
of the elastomeric material used which is quantified by
Shore A hardness values. The current PST materials
generally have Shore A hardness values ranging from about
25 43 to about 60 and are generally limited to a maximum of
about a 3 to 1 expansion ratio. Expansion over about 3:1
usually resulted in splitting or tearing of the tube.
Consequently, the diameter of the stretched elastomeric
tube is limited to about three times the size of the tube
30 in its unstretched condition. Further limitations are
imposed by the ability of the core material to support
the stretched tube without collapsing prematurely. The
more the PST is expanded, the greater is the force
exerted by the tube as it tries to recover.
35 Consequently, the core must be designed to withstand this
force. Where the core is designed for easy removability,
there is a trade-off between its wall thickness and its

-3-

ability to collapse on demand. To withstand higher forces, the wall thickness of the core must be increased. This adversely affects removability and cost of the core.

The range of sizes, i.e., external diameters of
5 spliced cable which may be protected by pre-stretched tubing, is limited. This limitation results from the balance which must be maintained between the recovery force exerted by the stretched elastomeric tube and the ability of the supporting core to resist crushing. The
10 range of cable diameters to which PSTs may be applied could be extended by use of a relatively soft PST with a high expansion ratio. Therefore, a need exists for a softer elastomer, suitable for use in pre-stretched tubes, which possesses an expansion ratio larger than
15 currently available materials. This higher ratio tubing could provide a PST for larger diameter cable and multilayer constructions suitable for high voltage applications.

Alternatives to single pre-stretched tubes have been
20 disclosed in the art. Two layer sleeves, i.e., sleeves applied as two separate tubes, for termination of electrical cables are disclosed in U.S. 4,714,800, (Atkins et al.). The first tube, applied next to the conductor, is a heat-shrink stress control tube. The
25 second tube is an insulator, the outer facing surface of which is convoluted.

Relatively rigid heat-shrinkable tubular structures are disclosed in U.S. 4,383,131, (Clabburn). The protective sleeve may comprise a conductive outer layer,
30 an insulating inner layer, and optionally a stress grading innermost layer.

Permanently elastic dielectric materials are disclosed in U.S. 4,363,842, (Kehr et al.). The materials are permanently resilient stress control
35 elements which yield at the site of application. The materials are formed into a member which slips over the cable, and not into a pre-stretched tubular member.

-4-

The use of PSTs as insulators in high voltage applications has increased in recent years. Current PSTs have provided effective insulation up to voltage ratings of about 600 volts. There is a need to increase this rating to as high as 5 kilovolts in high voltage applications. Also, there is a need to achieve these high voltage ratings using relatively soft rubbers such as ethylene propylene diene monomer rubber (EPDM). The dielectric strength of a selected rubber will indicate whether it is to be used for e.g., insulation or dielectric stress control. It is desirable for insulating materials to have a dielectric strength above about 450 V/mil in high voltage applications. Dielectric stress control requires the use of materials with dielectric strength values in the range of 90-160 V/mil. The higher the dielectric strength of the rubber, the thinner the PST wall can be, which results in less material used and less force on the support core which might cause it to collapse.

Further, the use of pre-stretched tubes as conductive shields for electrical cables has been limited in that, any conductivity is usually lost after expansion and recovery. It would be desirable for certain high voltage applications, to have a pre-stretched tube which would maintain an adequate amount of conductivity after expansion and recovery.

It is, therefore, an object of this invention to provide pre-stretched tubes comprised of low hardness, high expansion ratio elastomeric rubbers, supported on removable plastic cores for use in controlling dielectric stress.

Another object of this invention is to provide elastomeric pre-stretched tubes free from carbon black or containing amounts suitable for use in insulating spliced or terminated medium voltage to high voltage cables.

It has also been discovered that such elastomeric rubbers can be formulated with conductive fillers and

-5-

formed into pre-stretched tubes having an expansion of 2 to 3 times the original dimension which will maintain good electrical conductivity and hence good electrical shielding capability even after expansion and recovery.

5

Summary of the Invention

The present invention provides a multiplicity of articles comprising elastomeric tubular members supported in a stretched condition on easily removable cores, the
10 tubular members comprising:

- (a) from about 10 to about 60 percent of an oil-extended ethylene propylene diene monomer rubber,
- (b) from about 5 to about 25 percent of an elastomer selected from the group consisting of a nonoil-
15 extended ethylene propylene diene monomer rubber and nonoil-extended ethylene propylene rubber,
- (c) from about 5 to about 45 percent of an extender,
- (d) from about 10 to 30 percent of a processing oil,
- (e) from about 2 to about 30 percent of silica,
- 20 (f) from 0 to about 35 percent carbon black, and
- (g) up to about 30 percent of a polymeric plasticizer.

These terms have the following meanings as used herein.

1. The term "oil-extended" refers to a rubber in
25 which oil was added during polymerization.

2. The terms "extender" and "nonreinforcing filler" are used interchangeably to mean a non-reactive additive which reduces the amount of primary ingredients necessary in the formulation.

30 3. The term "PST" means pre-stretched tube or pre-stretched tubular member.

All percents, parts and ratios herein are by weight unless specifically noted otherwise.

One embodiment of the invention provides an
35 insulating PST article having a black tubular member. This article is useful in low voltage and medium voltage cables. Suitable PST materials of this type have a Shore

-6-

A hardness of less than about 33, and an expansion ratio of about 5 to 1. The 300% modulus should be below about 230 pounds per square inch. (1.6 MegaPascal). This PST may contain up to about 35% regular carbon black.

5 Another embodiment of the invention provides a nonblack or white insulating PST article. Suitable tubular members either contain no conductive fillers, e.g., carbon black, or use conductive fillers in amounts, e.g., less than 1.0 percent which yield insulative
10 compositions useful in medium voltage and high voltage applications. Suitable PST materials of this type have a Shore A hardness of less than about 38, and an expansion ratio of about 5 to 1. The 300% stretch modulus should be below about 300 pounds per square inch (2.1 MPa).

15 Another embodiment of the invention provides a PST useful for dielectric stress control. Stress control is achieved by incorporating high permittivity fillers into the rubbery polymer composition of the tubular members. Suitable PSTs of this type have a Shore A hardness value
20 of below about 45 and have low moduli, which allows an expansion ratio of about 4 to 1. The 300% modulus should be below about 400 pounds per square inch (2.8 MPa). Furthermore, the elastomeric material has a voltage rating in excess of 600 V. This material is used in IEEE
25 Class 1, 2 and 3 terminations for up to 35 KV rating.

Another embodiment of the invention provides a PST useful for electrical shielding applications. Suitable tubular members contain high amounts of conductive filler, such that even after expansion and recovery, good
30 electrical conductivity is maintained due to interparticle contact. Preferred articles contain at least about 25 percent conductive filler and have a volume resistivity of less than 200 Ω -cm. This PST material has a Shore A hardness of below about 70, and an
35 expansion ratio of about 3 to 1.

-7-

Brief Description of Drawing

Figure 1 is a graph showing the stress-strain behavior of various EPDM rubbers.

5 Detailed Description of the Invention

The pre-stretched tubes of the present invention have elastic recovery properties whereby the tubular components almost completely recover their original dimensions after the expansion forces are released. The
10 rubbers of the present invention have reduced hardness when compared to conventional elastomers having analogous applications, i.e., insulation, stress control, or shielding of medium and high voltage cables and the like. The lower hardness translates into higher expansion
15 ratios, and low moduli, thus allowing the materials to be stretched or expanded to greater ratios than conventional materials.

The materials exhibit good mechanical strength as well as excellent elastic memory such that they remain in
20 a stretched state without fracture over long periods of time, and, when allowed to shrink, recover quickly and almost completely. The material of the present invention may also be manufactured into PSTs and used in a multi-layer capacity.

25 Furthermore, due to the elasticity of the material, one size will cover a greater variety of cable dimensions than most currently available PSTs, without the need for specially reinforced support structures or cores. As the elastomeric tube is radially expanded, its wall thickness
30 decreases as the diameter of the stretched tube increases.

Another benefit of the softer elastomeric tube is the opportunity to develop combinations of concentric tubular compositions, which may include hard and/or soft
35 elastomers, so as to provide multilayer PSTs with tailored physical characteristics useful in a variety of applications.

-8-

Elastomeric materials used in PSTs need to have high tensile strength, high elongation, and a low modulus. It is desirable to exhibit a tensile strength of over 1000 pounds per square inch (6.9 MPa), determined using ASTM D412. For an insulative PST, the elongation should exceed at least about 850%, preferably 900% from the original resting length. For a stress control PST, the elongation should exceed at least about 800% from the original resting length. For a conductive PST, the elongation should exceed at least about 500% from the original resting length.

The modulus of the materials is also important. For an insulative PST useful in low voltage applications, the modulus should be sufficiently low such that less than 230 pounds per square inch (psi), (1.6 MPa), is required to elongate the sample 300%. For an insulative PST useful in medium and low voltage applications, the modulus should be such that less than 300 psi (2.1 MPa) is required to elongate the sample 300%. For a stress control PST, the modulus should be such that less than 400 pounds psi (2.8 MPa) is required to elongate the sample 300%. Finally, for a conductive PST, the modulus should be such that less than 1200 psi (8.3 MPa) is required to elongate the sample 300%. All moduli are determined according to ASTM D412.

The material of the present invention will generally be sold as a PST and, thus, should have an expansion ratio of at least about 5, for insulative PSTs, at least about 4 for PSTs used for stress control and at least 3 for shielding PSTs.

Elastic recovery is important so the tube fits snugly upon removal of the inner core. A desirable permanent set for all PSTs of the invention is less than about 23%. The large expansion ratio makes possible a greater wall thickness.

The elastomeric material of this invention should contain from about 10 to 60 percent oil-extended ethylene

-9-

propylene diene monomer (EPDM) or an oil-extended ethylene propylene rubber (EPM). More preferably, the invention should contain about 15 to 35 percent of an oil-extended EPDM. Suitable oil-extended rubbers include "Epsyn" P597 from Copolymer Company, and "Polysar" XC-955 available from Polysar Incorporated. These oil-extended EPDM rubbers contain 50 percent rubber solids and 50 percent paraffinic oil or naphthenic oil. Other useful commercially available oil-extended rubbers may contain different amounts/ratios of rubber resin and paraffinic oil, e.g., "Epsyn" P557 and "Epsyn" P558, both available from Copolymer Company, and "Vistalon" 3666, available from Exxon Company.

A nonoil-extended 100 percent solids EPDM or EPM rubber is also used in the amounts of about 5 to about 25 percent, more preferably about 10 to about 12 percent. Any commercially available EPDM or EPM rubber which is nonliquid at room temperature can be used; a preferred rubber is "Nordel" 1470, available from E.I. duPont de Nemours, (DuPont). Liquid EPDM is not recommended for use in compositions of the invention as an unacceptable reduction in elongation is frequently seen.

A processing oil is also added to the mixture to soften the material. There are many commercially available processing oils which would be compatible with the present invention. Preferably, up to about 30 percent of a processing oil is added to the mixture; in the case of a shielding PST, up to about 20 percent is preferred. Oils which may be used include paraffinic petroleum oil, naphthenic petroleum oil, and vegetable or animal derivative oils.

However, increasing the amount of processing oil alone does not create a soft, expandable PST. Rather, processing oil added in large quantities greatly impairs the integrity of the polymer. Unless the ratios of processing oil to rubber are properly chosen and compounded, the resulting material will not completely

-10-

cure. This causes weak mechanical and dielectric strength, poor elastic memory, and poor processibility.

PST articles of the invention may further comprise silica. Silica reinforces the strength of the rubber.

- 5 Useful silicas include hydrated precipitated silica or fumed silica. The PST article may comprise from about 2 to about 30 percent silica, preferably from about 4 to about 15 percent for insulating compositions. Lower amounts are preferred for stress control (0-10%) and
10 shielding (0-5%) compositions. One source of hydrated silica is "Hisil" 532 EP, available from PPG Industries Inc. Other useful silicas include "Hisil" 233, "Hisil" 210, silicas designated as Cabosil™, available from Cabot Corp., silicas designated as Aerosil™, available from
15 DeGussa, and the like.

- PST articles of the invention also comprise an extender, or nonreinforcing filler to dilute the rubber, thus increasing the mechanical elongation of the cured composition, as well as providing a cost reduction due to
20 the lesser amount of rubber required. Preferably, the extender comprises from about 5 to about 45 percent of the composition for insulating material. For stress control, the extender is preferably from about 5 to about 15 percent, and for conductive materials, preferably from
25 0 to about 5 percent. Useful extenders include aluminum trihydrate, clay, talc, kaolin, mica, calcium carbonate, magnesium carbonate, aluminum silicate, magnesium silicate, and the like.

- Polymeric plasticizers may also be included in
30 compositions of the invention. The amount of plasticizer varies with the viscosity of the polymer. Useful plasticizers include polybutenes, such as Indopol™ from AMOCO, and a liquid EPDM, such as Trilene™ available from Uniroyal Chemical. When desired, the useful levels of
35 polymeric plasticizer range up to about 30 percent, preferably 3 to 10 percent.

Insulative and dielectric stress control embodiments

-11-

of the present invention may also contain up to about 35 percent carbon black. Carbon black may consist of essentially any commercial grade, including large particulate size thermal types, fine reinforcing furnace grades, and materials termed "conductive carbon black". A preferred carbon black is a coarse furnace grade (i.e., having an average particle diameter of from about 40 to about 100 nanometers). Carbon black helps reduce dielectric stress by effectively controlling refraction of electrical flux lines associated with cable splices or terminations, yet allows maintenance of a desired level of elasticity.

Where a black, insulative PST for low voltage applications is desirable, the range of carbon black is preferably from about 7 to about 10 percent.

It has now been discovered that even with little or no carbon black, the insulative elastomeric articles of the invention will exhibit a high elongation, good elastic recovery, and high flexibility. Surprisingly, even in compositions of the invention containing less than 1 percent carbon black, the rubber will exhibit no splitting at a 5:1 stretch ratio. Further, the white rubber has higher insulative properties. Pre-stretched tubes using such white rubber are very useful in such applications as high voltage insulators, where conductivity is highly undesirable. Further, nonblack and white compounds are useful where color coding is desirable, and in non-electrical applications, e.g., dental products.

In PSTs useful for dielectric stress control, the preferred range of carbon black is from about 13% to about 30%.

Where a conductive PST is desirable for cable shielding, a highly conductive carbon black is required, which has an average particle size well below the range described above. These articles contain at least about 25% conductive carbon black.

-12-

Additives such as antioxidants, fungicides, organic silanes, powdered acrylics, lead oxides, zinc oxide and magnesium oxide may be added to compositions of the invention to vary the properties as desired. Useful
5 adjuvants include natural, surface treated, precipitated and hydrated materials.

The composition can be cured by a curing agent such as a peroxide or sulfur or by exposure to energizing radiation, e.g., ultraviolet radiation, electron beams,
10 radio frequency, microwaves, and the like. The preferred method of cure utilizes a peroxide curing agent. Possible peroxide curing agents include, but are not limited to dicumyl peroxide, 1,1-di(t-butyl peroxy) cyclohexane, 2,5-dimethyl-2,5-di(t-butylperoxy) hexane-3,
15 ethyl-3,3-di(t-butylperoxy) butyrate, 1,1-bis(t-butylperoxy), 3,3,5-trimethyl cyclohexane, 2,5-dimethyl-1-2,5-bis(t-butylperoxy) hexane, t-butyl cumyl peroxide, α,α' -bis(t-butylperoxy) diisopropylbenzene, n-butyl,4,4-bis(t-butylperoxy)valerate, and the like.

20 The optimum amount of peroxide depends on the specific peroxide used, the combination of polymeric materials, the acidity of the extenders and the amount of processing oil. Various EPDM rubbers may require different amounts of curing agent to yield the same
25 degree of crosslinking. The most preferred peroxide is α,α' -bis(t-butylperoxy)diisopropylbenzene. The preferred amount is from about 1 to about 5 percent, the most preferred amount is from about 2 to about 3.5 percent.

Pre-stretched tubular members useful for control of
30 dielectric stress further contain up to about 15% of a ceramic filler such as titanium dioxide or barium titanate. Such tubular members also contain up to about 2.5% aluminum flakes.

Articles of the invention are commonly supported by
35 interior cores. The core is made from a tough polymeric material such as flexible cellulose acetate butyrate, polyvinyl chloride or polypropylene. Cores for articles

-13-

of the invention may be formed by spirally wrapping an extruded ribbon and fusing or tacking at spaced points along the ribbon to form a rigid core which supports the PST. The core is thereafter removed by pulling one free
5 end of the ribbon core with sufficient force to separate the ribbon where it is tacked such that it becomes unwound. This permits the cover to relax onto an inserted cable or pipe, which leaves the PST tightly affixed over the cable or pipe.

10 Although the elastic material of the present invention is developed mainly for cable accessory and splicing applications, the materials, because of their excellent expansion ratio as well as elastic recovery, may find many applications in the utility, aerospace,
15 household, sports, games, toys or automotive industries.

Other uses for the elastomeric material include environmental protection for screwed cable fittings, knurled or hex nuts on flanges, flared or ferruled fittings, fittings for electrical plugs and cords,
20 bayonet or screwed lamp bases, electrical junctions, sockets or fuses, junctions, splices, or adjoining sleeve fittings for pipes transporting natural gas, water, or other gasses or liquids. Uses also include seals or gaskets, glands, faucets, valves or other mechanical
25 couplings or splices.

When the elastic material of the present invention is used as a sleeve for supporting cables, the sleeve is normally cylindrical both for the ease of manufacture and for maximum utility. Tubular structures of non-uniform
30 diameter are also contemplated as coming within the purview of the invention, a specific example being a conical structure for use as an endcap on a cable termination.

-14-

Test MethodsElastic Recovery

Elastic recovery is measured by the following method:

- 1) Stabilize an oven at 100° C.
- 5 2) Cut dumbbells from the sample to be tested using a Die C of ASTM D-412.
- 3) Mark parallel 1 inch (2.54 cm) bench marks at the approximate center of the sample. (Bench marks must be parallel.)
- 10 4) Place the dumbbell in the set fixture and stretch the sample until the distance between the bench marks is 2 inches (about 5 cm). This correlates to a 100% strain.
- 15 5) Place the loaded set fixture in a 100°C oven for 22 hours.
- 6) After the 22 hour heat cycle, remove the fixture from the oven and allow the stretched sample to cool at room temperature (21°C ± 3°C) for 60 minutes.
- 20 7) Remove the sample from the fixture and place the sample on a smooth wooden or cardboard surface. Release the sample gently.
- 8) After the sample has been out of the fixture for 30 minutes (± 2 minutes), measure and record the distance between the bench marks.
- 25 9) The calculation is as follows:

$$\text{The permanent set \%} = \frac{100 (RL-OL)}{TL-OL}$$

- 30 wherein RL = relaxed length (distance between bench marks after cooling)
OL = original length 1.00 inch (2.54 cm)
TL = test length 2.00 inch (5.08 cm)

35 Physical Properties

The modulus, elongation and tensile strength are measured using ASTM D412. The Shore A Hardness is tested using ASTM D2230. The dielectric strength is tested

-15-

using ASTM D149; the dielectric constant is tested using ASTM D150.

Volume Resistivity

5 The retention of conductivity is a major consideration for a conductive PST. The measurement of volume resistivity of tubing may be performed at various stretch ratios during expansion and at recovery.

10 The resistivity is recorded by clamping an electrode at both ends of a tube, which has been painted with conductive silver paint on both ends to reduce contact resistance, and measuring with an ohmmeter. The tubing is then expanded and loaded on a plastic cylindrical rod at a specified diameter to ensure the uniformity of
15 expansion. The rod has copper ends which provide the electrodes of resistivity measurement. The two ends of the tubing must contact the copper portion of the rod. After the measurement, the tubing is removed from the rod and loaded onto a rod having a larger diameter (for
20 expansion) or small diameter (for recovery). The volume resistivity is calculated by the equation

$$\text{Vol. Resist.} = R \frac{3.1416(D_o^2 - D_i^2)}{4L}$$

25

wherein D_o is the outside diameter of the tubing sleeve, D_i is the inside diameter of the tubing sleeve, R is the measured resistance, and L is the length of the tubing
30 sleeve.

High Voltage Tests

The material to be tested is fabricated into a tubular form. Two tests are run; a 15 KV test and a 25 KV test.

35 In the 15 KV test, the semiconductor cutback is 9 inches (23 cm.) and the length of the stress control tubular member used is 7.5 inches (19 cm.). The voltage is then applied to the material. This impulse test is

-16-

run at both positive and negative polarities. The BIL requirement for 15 KV tubular termination is 110 KV for both positive and negative polarities. The same test sample is then used for an AC step test, where 40 KV is first induced, and increased by 5 KV per 5 minute step.

In the 25 KV test, the semiconductor cutback is 15 inches (38 cm.) and the length of stress control tubular member tested is again 7.5 inches (19 cm.). The BIL test is performed by first running one pre-shot at 110 KV, and then increasing to 150 KV. Again, the test is run at both positive and negative polarities. The BIL requirement for 25 KV tubular termination is 150 KV for both the positive and negative polarities. The same test sample is then used for an AC step test, where 50 KV is first induced, and increased by 5 KV per 5 minute step.

Sample Preparation

The material can be either mill mixed or mixed in a closed mixer such as a Banbury mixer. When mill mixed, it is preferred to use a tight nip roll with cold water running through the rolls to maintain viscosity, improve dispersion and prevent any scorching of the material. In Banbury mixing, better viscosity maintenance and improved dispersion may be obtained by maintaining cold temperature in the mixer. This is preferably achieved by circulating cold water. Generally, carbon black (if used), precipitated silica and nonoil-extended EPDM are added first to obtain better dispersion followed by an oil-extended rubber. After thorough mixing of all ingredients, the curing agent may be added to the mixture. The temperature must be maintained below the decomposition temperature of the curing agent to prevent any premature curing.

The composition can then be formed into a tube using a cold feed extruder equipped with a venting port to help reduce air trapped in the feedstock. The feedstock is extruded as tubing which is then vulcanized, e.g., in an

-17-

autoclave using steam. Conventional process aids, process oils, coupling agents, and vulcanizing agents can be included in the compounded elastomeric component.

As mentioned, one of the key characteristics of the present invention is the softness of the material. Black insulating embodiments of the present invention have hardness values of below about 33 Shore A. Shore A hardness is determined according to ASTM D-2240.

The following Table shows Samples A, B, and C which were similar in all respects except for the amount of oil in the samples. The properties were measured and it can be seen that the 300% modulus and the tensile break strength diminished significantly as the amount of oil increased. At the same time, the ability of the elastomer to recover, as indicated by the change in permanent set, is adversely affected by increasing the amount of processing oil. If the permanent set values increase much above about 23%, their value in PST applications is diminished. The problems observed from excess oil added to the materials include oil bleeding out from the rubber, gas generation during curing, and retardation of the cure system.

<u>Table 1</u>				
	<u>Sample A</u>	<u>Sample B</u>	<u>Sample C</u>	
25	70	120	140	
Oil Loading, parts per hundred resin (Phr)				
<u>Properties:</u>				
	46	34	29	
	660	300	210	
30	670	850	930	
	1578	1295	1056	
	13	21	29	

The technique used in the present invention remedies the above-mentioned oil problems by the following:

- 1) using lower volatility plasticizers to

-18-

replace part of the process oil;

2) using polymer bound oil which has a higher compatibility level than free oil;

3) using more peroxide or coagents to
5 compensate for the effects of the oil.

Using more peroxide to improve cure has to be done with caution due to excess peroxide tending to increase the modulus and hardness and reduce the elongation drastically, all of which are not desirable
10 for making a high stretch, low hardness compound.

Example 1 is a typical formulation of a low modulus composition of the invention. The formulation uses an oil-extended EPDM rubber ("Polysar" XC-955), together with a nonoil-extended EPDM rubber ("Nordel"
15 1470) and the proper selection of other ingredients including process oil, polymeric plasticizer (polybutene), peroxide curative, lead oxide, fungicide, processing aids, antioxidants and coupling agents. This formulation, and those included in the other examples are
20 presented using a basis of parts per hundred rubber resin (phr). This represents the combined total of rubber solids present in the composition. Thus, the specified amount of a given component, in any formulation, indicates the quantity to be added for each 100 parts of
25 rubber resin. As indicated previously, where components are described as percentages, the weight of a specified component is used as a basis for measurement. Thus weight percent for e.g., "Polysar XC-955" in Example 1 is 33.6% when stated as a percentage of the total formula
30 weight.

-19-

Example 1

	<u>Chemical</u>	<u>Phr</u>	<u>Note</u>
	"Polysar" XC-955	120	Oil-extended EPDM Rubber
	"Nordel" 1470	40	EPDM Rubber
5	"Hisil" 532 EP	20	Precipitated Hydrated Silica
	"Sunpar" 2280	60	Paraffinic Petroleum Oil
	Zinc Oxide	5	Zinc Oxide
10	"Agerite" White	0.8	Antioxidant
	"Ultranox" 257	1.5	Antioxidant
	"Struktol" WB-16	2	Mixture of Calcium Fatty Acids
	Red Lead	4	Red Lead Oxide, Pb_3O_4
15	"Furnex" N754	30	Carbon Black
	"Vinyzene" SB-1 ELV	1.5	Fungicide
	"Hydral" 710	45	Aluminum Trihydrate
	"Ucarcil" RC-1	1	Organic Silane
20	"SR-297"	6	1, 3-Butylene Glycol Dimethacrylate
	"Indopol" H-300	10	Polybutene
25	"Vulcup" 40 KE	9.5	α, α' -bis(ter-Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
	TOTAL	356.3	

30

The following Table shows a comparison of the low hardness rubber of Example 1 compared to a commercially available PST rubber.

35

-20-

Table 2

The Comparison of Physical Properties of Low Hardness Rubber (Example 1) with a Typical PST Rubber

5	<u>Properties</u>	<u>Low Hardness Rubber (Example 1)</u>	<u>Typical PST Rubber</u>
	Hardness, Shore A	28	46
10	100% Modulus, psi	80	160
	200% Modulus, psi	110	370
	300% Modulus, psi	145	680
	500% Modulus, psi	260	-
	700% Modulus, psi	420	-
15	900% Modulus, psi	620	-
	Tensile Strength, psi	1290	1600
	Elongation @ Break	1090	680
	100% Permanent Set, %	13.0	13.0
	Dielec. Strength V/mil	580	400
20	Dielec. Const. @ 1500 V	3.7	5.4
	Dissipation Factor	0.015	0.045

Table 2 shows the properties of the low modulus compound of Example 1 compared to a typical PST compound. The typical PST compound has a Shore A hardness of 46. The low modulus compound has a 28 Shore A hardness. Modulus values listed in Table 2 give a good comparison between extensibility of the two rubbers. The data indicate the force required to stretch a typical PST rubber to 300% is enough to stretch a low modulus rubber more than 900%. The ultimate elongation of the low modulus formulation is about 1.5 times more than the typical PST. If this factor is taken into account, the true tensile strength at the breaking point of the Example 1 rubber is greater than the typical PST rubber. The permanent set value demonstrates that the Example 1 rubber has almost the same elastic recovery as a typical PST rubber. The low modulus rubber also

-21-

shows better electrical insulating performance as compared to a typical PST rubber. The dielectric strength of Example 1 is above 450 V/mil, which is preferable.

5 Figure 1 shows the stress strain curve of EPDM rubbers with various hardnesses. The different curves represent different Shore A hardnesses. The following are the various curves and their associated values.

10	<u>Curve</u>	<u>Shore A Hardness</u>
	A	78
	B	45
	C	35
	D	30
15	E	28

The figure is a good representation of how easily the material can be elongated. A 78 Shore A rubber is not easily stretched and will break at less than 300% elongation. A 45 Shore A rubber is a typical PST compound. It has a modulus and elongation range that makes it extensible and allows it to be maintained in an expanded shape without breaking. The curves show how the modulus and elongation change with the change of hardness. As the curves indicate, the low hardness rubbers have very low modulus and greater elongation which allows them to be easily expanded to a much greater degree than the high hardness rubbers.

The low modulus, high stretch rubbers exhibit several outstanding characteristics that are very critical to PSTs. One is the ability to be loaded on a core and remain in a high degree of extension for a long period of time without splitting or breaking apart. Another is substantial elastic recovery after being stretched for a long period of time. Since a PST will be in an expanded state during storage before it is used, it has to be resistant against

-22-

splitting on the core or collapsing the core before it is used. In order to ascertain whether the tubing will split or collapse during storage, a test to simulate long-term storage of the PST was developed.

- 5 The test is performed by expanding the tube radially to a certain degree of extension and thereafter loading the tube on a plastic core. The stretch ratio is determined, for example, by loading a 0.4 inch (1 cm) I.D. tubing on a 2 inch (5.08 cm) O.D. plastic core. The resulting stretch ratio is 4:1, and, for example, if placed on a 2.4 inch (6.1 cm) core, a 5:1 stretch ratio is achieved. The PST is then placed in an oven pre-set at 60° C. The tubing is thereafter constantly inspected to see if
- 15 splitting has occurred.

The following Table 3 shows the splitting results for the low modulus compound of Example 1.

<u>Table 3</u>			
20	<u>Characteristics</u>	<u>Regular PST</u>	<u>High stretch PST</u> (Example 1)
	Shore A Hardness	46	29
	Permanent Set %	13	13
25	<hr/>		
	<u>Oven Split Test</u>	(Number of tubes split out of a total of 4 tubes)	
	<u>Stretch Ratio</u>	<u>Number of Tubes Split</u>	
30		<u>Regular PST</u>	<u>Example 1</u>
	3:1	0	0
	4:1	4	0
	5:1	4*	0
	*4 Tubes split and/or the cores collapsed		

35

The results from Table 3 indicate regular PST can be stretched to a 3:1 stretch ratio and survive the oven test, at 4:1 the tube splits rapidly, and, if stretched to 5:1, the tube splits or the core

-23-

collapses. The high-stretch insulating PST of Example 1 can be stretched beyond about a 5:1 stretch ratio without splitting or collapsing the core due to its high expansion capability and its low modulus.

5 Also shown in Table 3 is the fact that the high-stretch insulative PST of Example 1 has as good a permanent set value as a conventional PST. Permanent set is a measure of elastic recovery of an elastomeric material. The permanent set is a very
10 important property and indicates the final dimensions of the tubing after the core is removed. The tubing will often be subjected to high stretch (e.g., 5:1) and stored for long periods of time. Thus, to ensure a proper fit of the PST after removal of the support
15 core, the permanent set should not exceed 23%.

Comparative examples 2C and 3C show formulations omitting a nonoil-extended EPDM rubber. The properties of comparative examples 2C and 3C are not satisfactory for low-hardness rubbers. Comparative
20 example 3 meets every requirement with the exception of a high permanent set. Comparative example 2C shows excellent elastic recovery, but insufficient elongation.

25

-24-

	<u>Chemical</u>	<u>Example 2C</u> <u>Phr</u>	<u>Example 3C</u> <u>Phr</u>	<u>Note</u>
	"Polysar" XC-955	200	-	Oil-extended EPDM Rubber
5	"Epsyn" N997	-	200	Oil-extended EPDM Rubber
	"Statex" N550	30	40	Carbon Black
10	"Hisil" 532 EP	35	25	Precipitated Hydrated Silica
	"Sunpar" 2280	50	30	Paraffinic Petroleum Oil
15	Zinc Oxide	5	5	Zinc Oxide
	"Agerite" MA	1.25	1.25	Polymerized 1,2-Dihydro-2,2,4-trimethylquinoline
20	"Factice"	20	20	Vulcanized Vegetable Oil
	"Struktol" WB-16	2	2	Mixture of Calcium Fatty Acids
25	"TRD" 90	4	4	Red Lead
	"Ucarcil" RC-1	1	1	Organic Silane
30	"SR-297"	8	8	1,3-Butylene Glycol Dimethacrylate
	"Dicup" 40 KE	16	0	Dicumyl Peroxide on Burgess KE Clay
35	"Vulcup" 40 KE	0	10	α, α' -bis(ter-Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
	TOTALS	372.25	346.25	

40

	<u>Properties</u>	<u>Example 2C</u>	<u>Example 3C</u>
	Hardness, Shore A	30	28
	100% Modulus, psi	66	79
	200% Modulus, psi	123	125
45	300% Modulus, psi	233	202
	Tensile Strength, psi	1065	1387
	Elongation @ Break	821	881
	100% Permanent Set, %	15.1	31.3
	Dielec. Strength, V/mil	448	256
50	Dielec. Constant	4.1	5.3
	Dissipation Factor	0.024	0.036

-25-

As shown in the following Examples 4 and 5, by using a different proportion of the nonoil-extended EPDM polymer and the oil-extended EPDM polymer from Example 1, the desired properties of the low modulus rubber can be achieved by balancing the amount of silica, carbon black, processing oil and polymeric plasticizer. Both Examples 4 and 5 exhibit low modulus, low hardness, high elongation and good elastic recovery properties. Example 5 contains just a trace of carbon black which is used as a coloring compound. A non-black, low hardness rubber can be made by replacing the carbon black with precipitated hydrated silica.

-26-

	<u>Chemical</u>	<u>Example 4</u> <u>Phr</u>	<u>Example 5</u> <u>Phr</u>	<u>Note</u>
5	"Polysar" XC-955	50	80	Oil-extended EPDM Rubber
	"Nordel" 1470	75	60	EPDM Rubber
	"Furnex" N754	30	0.3	Carbon Black
10	"Hisil" 532EP	20	45	Precipitated Hydrated Silica
	"Sunpar" 2280	65	60	Paraffinic Petroleum Oil
15	Zinc Oxide	5	5	Zinc Oxide
	"PLX" 841	1	1	Antioxidant Blend
20	"Ultranox" 257	1.5	1.5	Antioxidant
	Red Lead	4	3	Red Lead Pb_3O_4
	"Struktol" WB-16	2	4	Mixture Oxide of Calcium Fatty Acids
25	"Vinyzene" SB-1 ELV	1.5	1.5	Fungicide
30	"Hydral" 710	40	60	Aluminum Trihydrate
	"Ucarcil" RC-1	1	1	Organic Silane
	"SR-297"	6	6	1,3-Butylene Glycol Dimethacrylate
35	"Indopol" H-300	20	15	Polybutene
40	"Vulcup" 40 KE	9	9	α, α' -bis(ter-Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
	TOTALS	331	352.3	

-27-

	<u>Properties</u>	<u>Example 4</u>	<u>Example 5</u>
	Hardness, Shore A	30	30
	100% Modulus, psi	83	70
	200% Modulus, psi	125	105
5	300% Modulus, psi	180	140
	500% Modulus, psi	-	250
	700% Modulus, psi	-	410
	Tensile Strength, psi	1250	1190
	Elongation @ Break	1028	1000
10	100% Permanent Set, %	12.9	12.9
	Dielec. Strength V/mil	537	487
	Dielec. Constant @ 1500 V	3.4	2.5
	Dissipation Factor	0.018	0.017

15

Example 6

Non-Black Pre-Stretched Tubular Membrane

	<u>Chemical</u>	<u>Part (phr)</u>	<u>Note</u>
	"Polysar" XC-955	200	Oil Extended EPDM
20	"Agerite Stalite-S"	3	Mixture of Octylated Diphenylamines
	"Vanox" ZMTI	1	Zinc 2-mercaptopolyimidazole
	"TE-80"	2	Fatty Acid Mixtures
	"Ucarsil" RC-1	1.5	Organofunctional Silane
25	"Burgess" CB	50	Treated Aluminum Silicates
	"Hisil" 532 EP	40	Precipitated Hydrated Silica
	Zinc Oxide	5	Zinc Oxide
30	TRD-90	4	Red Lead Dispersion
	"Indopol" H-100	45	Polybutene
	"Microcheck" 11-D	1.5	Fungicide
	"Drimix" SR297-75E	6.5	1,3 Butylene Glycol Dimethacrylate
35	"Vulcup" 40 KE	7.5	α, α' -bis(ter-Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
40	TOTAL	367	

-28-

Physical properties:

	100% Modulus	66 psi
	200% Modulus	98 psi
	300% Modulus	156 psi
5	Tensile Strength	1022 psi
	Ult. Elongation	949%
	Hardness, Shore A	28
	Permanent Set, 22 hr. @ 100°C	11.7%
10	Dielec. Strength V/mil	610
	Dielec. Constant	2.91
	Dissipation Factor @ 23°C, 1200 Volt	0.0092

15

-29-

Example 7

Stress Control PST with High Permittivity

	<u>Chemical</u>	<u>Part (phr)</u>	<u>Note</u>
	"Epsyn" 7506	40	EPDM Rubber
5	"Polysar" XC-955	120	Oil Extended EPDM
	"PLX 854"	1.5	Antioxidant Blend
	"Ultranox" 257	1.5	Phenol, 4-methyl, Reaction Products with Dicyclopentadiene and Isobutylene
10	"Ucarsil" RC-1	1	Organofunctional Silane
	Zinc Oxide	5	Zinc Oxide
	"Tipure" R902	15	Titanium Dioxide
	"Sunpar" 2280	30	Paraffinic Oil
15	"Indopol" H-300	5	Polybutene
	"Statex" N550	35	Carbon Black
	"Furnex" N754	45	Carbon Black
	"Ticon" P	30	Barium Titanate
	"WB-16"	2	Fatty Acid Mixture
20	"Silberline" DF 1651	9.4	Aluminum Flakes
	"Drimix" SR-197-75E	5	1,3 Butylene Glycol Dimethacrylate
	"Vulcup" 40 KE	7.6	α , α' -bis(ter- Butylperoxy)Diisopropyl Benzene on Burgess KE clay
25			
	TOTAL	353	

-30-

	<u>Property</u>	<u>Example 7</u>
	100% Modulus, psi	133
	200% Modulus, psi	231
	300% Modulus. psi	389
5	Tensile Strength, psi	1735
	Ult. Elongation, %	835
	Hardness, Shore A	42
	Permanent Set, 22 hr. @ 100°C	
10	100%/30 Min. Recovery, %	14.1
	Dielec. Strength V/mil	105
	Dielec. Constant	
	Dissipation Factor	
	@ 23°C, 1200 Volt	0.11
15		

The high voltage test results for Example 7 are shown in below. Example 7A is a test on a class 3 termination with Example 7 applied as the stress control component at 15 KV voltage rating with 9 inch (23 cm.) cutback of the semiconductor layer of the tube. Example 7B shows a 25 KV voltage rating with 15 inch (38 cm.) cutback of the semiconductor layer of the tube.

	<u>Example 7A</u>	
	<u>Test</u>	<u>Result</u>
25	Partial Discharge	
	CSV (KV-RMS)	50
	CEV (KV-RMS)	-
30	BIL Surges	
	KV-Crest	+113
	KV-Crest	-111
	5 minute AC Step Test	
35	KV-RMS	80
	Maximum Impulse	
	KV-Crest	+170
	KV-Crest	-171
40		

-31-

	<u>Test</u>	<u>Example 7B</u>	<u>Result</u>
5	Partial Discharge		
	CSV (KV-RMS)		46
	CEV (KV-RMS)		41
	BIL Surges		
	KV-Crest		+152
10	KV-Crest		-152
	5 minute AC Step Test		
	KV-RMS		90
15	Maximum Impulse		
	KV-Crest		+188
	KV-Crest		-173

20

As can be seen, the composition of the invention passed both the 15 KV and 25 KV testing. Examples 8-10 demonstrate conductive PST materials useful for electric shielding.

25

Example 8

	<u>Chemical</u>	<u>Part (phr)</u>	<u>Note</u>
30	"Nordel" 1470	40	EPDM Rubber
	"Polysar" XC-955	120	EPDM Rubber, 50% Oil Extended
	"Agerite MA"	1.5	Antioxidant Blend
	"Ucarsil" RC-1	1.5	Organofunctional Silane
35	Zinc Oxide	3	Zinc Oxide
	"Sunpar" 2280	55	Paraffinic Oil
	"Conductex" 975	75	Conductive Carbon Black
	"Ketjen" EC-300J	26	Conductive Carbon Black
	"SR-297"	3	1,3 Butylene Glycol Dimethacrylate
40	"Vulcup" 40 KE	9.1	α, α' -bis(ter-Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
45	TOTAL	334.1	

Total Carbon Black, 30.7%

-32-

Physical properties:

	100% Modulus	246 psi
	300% Modulus	1023 psi
	Tensile Strength	2116 psi
5	Ult. Elongation	566%
	Hardness, Shore A	61
	Permanent Set	17%
	Volume Resistivity	21 ohm.cm

10 Conductivity after recovery for a sample according to example 8 was tested. The original volume resistivity of the tubing was 41.8 ohm-cm (as opposed to the slab sample tested above at 21 ohm-cm). The volume resistivity increased when the

15 sample was stretched to 150% and then decreased at 280% stretch. During the recovery, volume resistivity increased when the tube recovered to 176% stretch ratio and then decreased when it was recovered further. In all, the original low volume

20 resistivity maintains a low value throughout the entire process of expansion and recovery. As can be seen for this particular rubber the volume resistivity never goes beyond 150 ohm-cm under the influence of mechanical stress and strain.

25

		Expansion		Recovery	
	<u>Original</u>	<u>150%</u>	<u>280%</u>	<u>175%</u>	<u>140%</u>
Volume Resist.	42	100	61	147	133

-33-

Comparative Example 9C

	<u>Chemical</u>	<u>Part (phr)</u>	<u>Note</u>
	"Trilene" 65	50	Liquid EPDM Rubber
5	"Polysar" XC-955	100	EPDM Rubber, 50% Oil Extended
	"Agerite" MA	1.5	Antioxidant
	"Ucarsil" RC-1	1.5	Organofunctional Silane
	Zinc Oxide	3	Zinc Oxide
	"Sunpar" 2280	65	Paraffinic Oil
10	"Carbowax" PEG 3350	1.5	Polyethylene Glycol
	"Conductex" 975	65	Conductive Carbon Black
	"Ketjen" EC-300J	30	Conductive Carbon Black
	"SR-297"	3	1,3 Butylene Glycol Dimethacrylate
15	"Vulcup" 40 KE	8.5	α, α' -bis(ter- Butylperoxy)Diisopropyl Benzene on Burgess KE
	TOTAL	264	

20

Total Carbon Black, wt% 36.0%

Physical properties:

	100% Modulus	737 psi
25	300% Modulus	-
	Tensile Strength	1184 psi
	Ult. Elongation	162%
	Hardness, Shore A	77
	Permanent Set	20.4%
30	Volume Resistivity	8 ohm-cm

As can be seen in the above example, the use of liquid EPDM may result in generally good physical characteristics. However, the ultimate elongation is

35 unacceptably low.

-34-

Example 10

	<u>Chemical</u>	<u>Part (phr)</u>	<u>Note</u>
	"Polysar" XC-955	200	EPDM Rubber, 50% Oil Extended
5	"Agerite" MA	1.5	Antioxidant
	"Ucarsil" RC-1	2	Organofunctional Silane
	Zinc Oxide	5	Zinc Oxide
	"Sunpar" 2280	35	Paraffinic Oil
	"Conductex" 975	100	Conductive Carbon Black
10	"Ketjen" EC-300J	35	Conductive Carbon Black
	"SR-297"	3	1,3 Butylene Glycol Dimethacrylate
	"Vulcup" 40 KE	8.7	α, α' -bis(ter- Butylperoxy)Diisopropyl Benzene on Burgess KE Clay
15			
	TOTAL	390.2	

Total Carbon Black, wt% 34.6%

20

Physical properties:

	100% Modulus	293 psi
	300% Modulus	1124 psi
	Tensile Strength	1698 psi
25	Ult. Elongation	500%
	Hardness, Shore A	69
	Permanent Set	28.3%
	Volume Resistivity	11 ohm-cm

30 The scope of the invention is not limited to the specific details set forth herein for purposes of illustration, but is solely defined by the claims. Various modifications are possible without departing from the spirit of the invention.

35

-35-

What is Claimed is:

1. An article comprising an elastomeric tubular member supported in a stretched condition on an easily removable core, said tubular member comprising:
 - a) from about 10 to about 60 percent of an oil-extended ethylene propylene diene monomer rubber,
 - 10 b) from about 5 to about 25 percent of an elastomer selected from the group consisting of nonoil-extended ethylene propylene diene monomer rubber and nonoil-extended ethylene propylene rubber,
 - 15 c) from about 5 to about 45 percent of an extender,
 - d) from about 10 to about 30 percent of a processing oil,
 - e) from about 2 to about 30 percent of silica,
 - 20 and
 - f) from 0 to about 30 percent of a polymeric plasticizer.
2. The article of claim 1 further containing
25 about 1 to 5 percent of peroxide as a curing agent.
3. The article of claim 1 having a permanent set of less than about 23%.
- 30 4. The article of claim 1 wherein said extender is selected from the group consisting of aluminum trihydrate and aluminum silicate.
5. An insulative article useful in low voltage
35 applications comprising the elastomeric tubular member of claim 1 further containing up to about 35 percent carbon black, said tubular member having a

-36-

Shore A hardness value of less than about 33, a 300% stretch modulus below about 230 pounds per square inch, an elongation of at least about 850%, and an expansion ratio of about 5 to 1.

5

6. The article of claim 5 wherein said article contains from about 7 to about 10 percent carbon black.

10

7. The article of claim 5 further containing about 1 to 5 percent of peroxide as a curing agent.

8. The article of claim 5 having a dielectric strength above about 450 V/mil.

15

9. A nonblack insulative article useful in medium and high voltage applications comprising the elastomeric tubular member of claim 1, containing less than about 1% carbon black, wherein said tubular member has a Shore hardness value of less than about 38, a 300% stretch modulus below about 300 pounds per square inch, an elongation of at least about 850%, and an expansion ratio of about 5 to 1.

25

10. An article useful for dielectric stress control comprising an elastomeric tubular member supported in a stretched condition on an easily removable core, said tubular member comprising:

- 30 a) from about 10 to about 60 percent of an oil-extended ethylene propylene diene monomer rubber,
- b) from about 5 to 25 percent of an elastomer selected from the group consisting of a nonoil-extended ethylene propylene diene monomer rubber and nonoil-extended ethylene propylene rubber,
- 35 c) from about 5 to about 15 percent of an extender,

-37-

- d) from about 10 to about 30 percent of a processing oil,
e) from 0 to about 10 percent of silica,
f) from about 10 to about 35 percent carbon black,
g) from 1% up to about 15% of a ceramic filler selected from titanium dioxide and barium titanate, and
h) from 0 to about 30 percent of a polymeric plasticizer, wherein said tubular member has a Shore A hardness value of below about 45, an elongation of at least about 800%, a 300% stretch modulus below about 400 pounds per square inch, and an expansion ratio of about 4 to 1.

11. An article according to claim 10 having a dielectric strength of from about 90 to about 160 V/mil.

12. An article according to claim 10 further comprising from about 1% to about 3% aluminum flakes.

13. The article of claim 10 further containing about 1 to about 5 percent of peroxide as a curing agent.

14. A conductive article useful for shielding high voltage cables comprising an elastomeric tubular member supported in a stretched condition on an easily removable core, said tubular member comprising:

- a) from about 10 to about 60 percent of an oil-extended ethylene propylene diene monomer rubber,
b) from about 5 to about 25 percent of an elastomer selected from the group consisting of

-38-

a nonoil-extended ethylene propylene diene monomer rubber and nonoil-extended ethylene propylene rubber,

c) from 0 to about 5 percent of an extender,

5 d) from 0 to about 20 percent of a processing oil,

e) from 0 to about 5 percent of silica,

f) at least about 25 percent of a highly conductive carbon black, and

10 h) from 0 to about 15 percent of a polymeric plasticizer, wherein said tubular member has a Shore A hardness value of below about 70, an elongation of at least about 500%, a 300% stretch modulus below about 1200 pounds per

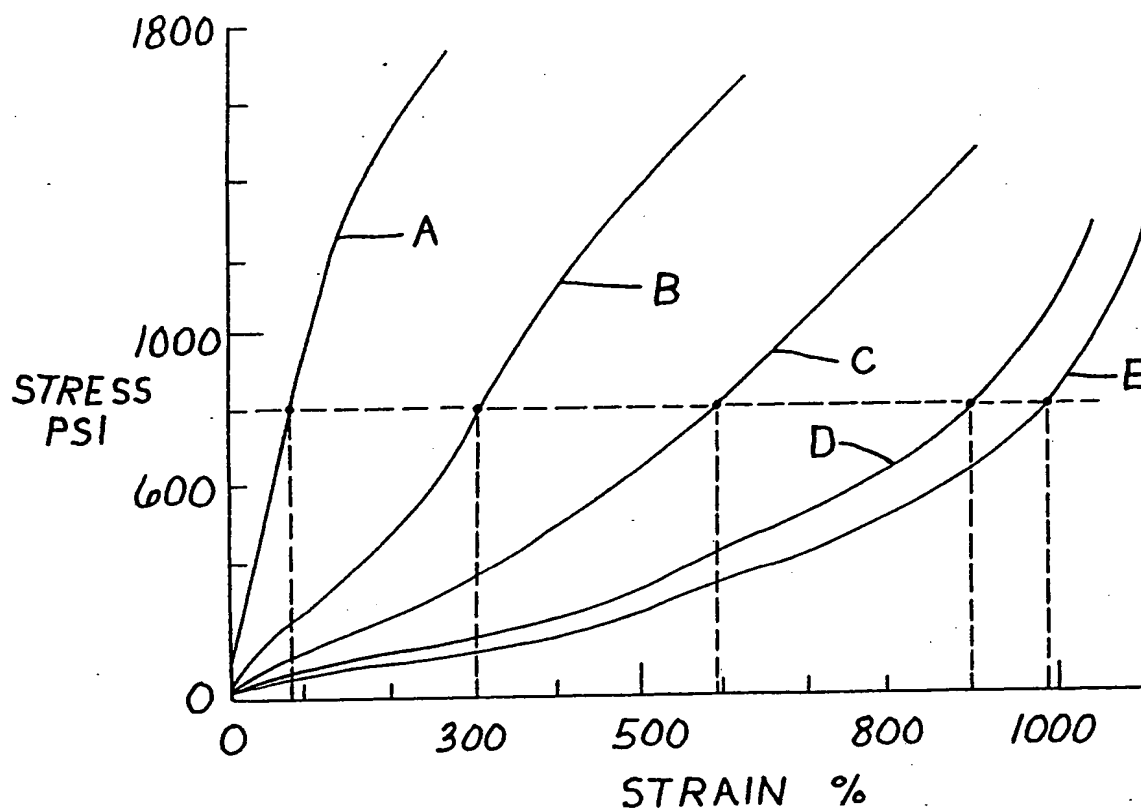
15 square inch, and an expansion ratio of about 3 to 1.

15. The article of claim 14 further containing about 1 to about 5 percent of peroxide as a curing

20 agent.

16. The article of claim 14 having a volume resistivity of less than 200 ohm-cm.

1/1



INTERNATIONAL SEARCH REPORT

PCT/US 91/0242

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁸ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁵ : C 08 J 5/18, H 02 G 15/00	
II. FIELDS SEARCHED	
Classification System	Minimum Documentation Searched ⁷
IPC ⁵	Classification Symbols C 08 J, H 02 G, H 01 R
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁶	

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		Relevant to Claim No. ¹³
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	
X	EP, B1, 0 035 271 (MINNESOTA MINING AND MANUFACTURING COMPANY) 09 September 1981 (09.09.81), see claims; page 3, line 58 - page 4, line 3.	1, 5, 6 10, 12 14
X	US, A, 4 363 842 (NELSON) 14 December 1982 (14.12.82), see claims; column 3, line 59 - column 4, line 2.	1, 5, 6 10, 12 14
X	US, A, 4 517 407 (FOX et al.) 14 May 1985 (14.05.85), see claims; column 5, lines 17-28.	1, 14
A	US, A, 4 303 571 (JANSEN et al.) 01 December 1981 (01.12.81), see claims.	1

- ¹⁰ Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
 - "E" earlier document but published on or after the International filing date
 - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 - "O" document referring to an oral disclosure, use, exhibition or other means
 - "P" document published prior to the International filing date but later than the priority date claimed

- "T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "Z" document member of the same patent family

IV. CERTIFICATION	
Date of the Actual Completion of the International Search <div style="text-align: center; margin-top: 10px;">04 July 1991</div>	Date of Mailing of this International Search Report <div style="text-align: center; margin-top: 10px;">22 JUL 1991</div>
International Searching Authority <div style="text-align: center; margin-top: 10px;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer <div style="text-align: center; margin-top: 10px;"> MISS T. TAZELAAR </div>

ANHANG

zum internationalen Recherchen-
bericht über die internationale
Patentanmeldung Nr.

ANNEX

to the International Search
Report to the International Patent
Application No.

ANNEXE

au rapport de recherche inter-
national relatif à la demande de brevet
international n°

PCT/US91/02422 SAE 47005

In diesem Anhang sind die Mitglieder
der Patentfamilien der im obenge-
nannten internationalen Recherchenbericht
angeführten Patentdokumente angegeben.
Diese Angaben dienen nur zur Unter-
richtung und erfolgen ohne Gewähr.

This Annex lists the patent family
members relating to the patent documents
cited in the above-mentioned inter-
national search report. The Office is
in no way liable for these particulars
which are given merely for the purpose
of information.

La présente annexe indique les
membres de la famille de brevets
relatifs aux documents de brevets cités
dans le rapport de recherche inter-
national visée ci-dessus. Les renseigne-
ments fournis sont donnés à titre indica-
tif et n'engagent pas la responsabilité
de l'Office.

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
EP-B1- 35271	08-05-85	AU-A1-67969/81	10-09-81
		AU-B2- 544317	23-05-85
		BR-A - 8101228	08-09-81
		CA-A1- 1145926	10-05-83
		DE-A1- 3008264	10-09-81
		DE-C2- 3008264	05-01-83
		DE-C0- 3170369	13-06-85
		EP-A1- 35271	09-09-81
		ES-A1- 499969	16-05-82
		ES-A5- 499969	15-06-82
		ES-A1- 8204871	16-08-82
		JP-A2-56139544	31-10-81
		MX-A - 157640	08-12-88
		NZ-A - 196397	12-04-83
		ZA-A - 8101363	28-04-82
<hr/>			
US-A - 4363842	14-12-82	Keine - None - Rien	
<hr/>			
US-A - 4517407	14-05-85	Keine - None - Rien	
<hr/>			
US-A - 4303571	01-12-81	CA-A1- 1164135	20-03-84
		DE-C0- 3162916	10-05-84
		DK-A - 209/81	18-07-81
		EP-A2- 32804	29-07-81
		EP-A3- 32804	12-08-81
		EP-B1- 32804	04-04-84
		JP-A2-56104952	21-08-81
		JP-B4- 1024819	15-05-89
<hr/>			
<hr/>			
<hr/>			
<hr/>			

This Page Blank (uspto)